Sudden cardiac arrest during the COVID-19 pandemic: A two-year prospective evaluation in a North American community

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BACKGROUND Early during the coronavirus disease 2019 (COVID-19) pandemic, higher sudden cardiac arrest (SCA) incidence and lower survival rates were reported. However, ongoing effects on SCA during the evolving pandemic have not been evaluated.

OBJECTIVE The purpose of this study was to assess the impact of COVID-19 on SCA during 2 years of the pandemic.

METHODS In a prospective study of Ventura County, California (2020 population 843,843; 44.1% Hispanic), we compared SCA incidence and outcomes during the first 2 years of the COVID-19 pandemic to the prior 4 years.

RESULTS Of 2222 out-of-hospital SCA cases identified, 907 occurred during the pandemic (March 2020 to February 2022) and 1315 occurred prepandemic (March 2016 to February 2020). Overall age-standardized annual SCA incidence increased from 39 per 100,000 (95% confidence [CI] 37–41) prepandemic to 54 per 100,000 (95% CI 50–57; P <.001) during the pandemic. Among Hispanics, incidence increased by 77%, from 38 per 100,000 (95% CI 34–43) to 68 per 100,000 (95% CI 60–76; P <.001).

Among non-Hispanics, incidence increased by 26%, from 39 per 100,000 (95% CI 37–42; P <.001) to 50 per 100,000 (95% CI 46–54). SCA incidence rates closely tracked COVID-19 infection rates. During the pandemic, SCA survival was significantly reduced (15% to 10%; P <.001), and Hispanics were less likely than non-Hispanics to receive bystander cardiopulmonary resuscitation (45% vs 55%; P = .005) and to present with shockable rhythm (15% vs 24%; P = .003).

CONCLUSION Overall SCA rates remained consistently higher and survival outcomes consistently lower, with exaggerated effects during COVID infection peaks. This longer evaluation uncovered higher increases in SCA incidence among Hispanics, with worse resuscitation profiles. Potential ethnicity-specific barriers to acute SCA care warrant urgent evaluation and intervention.

KEYWORDS Bystander cardiopulmonary resuscitation; COVID-19; Ethnicity; Hispanic; Pandemic; Sudden cardiac arrest

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Introduction

Out-of-hospital sudden cardiac arrest (SCA) is a mostly fatal condition, with an annual incidence of 40–80 per 100,000, and an average survival rate of 9% in the United States.[1,2] Early reports during the coronavirus disease 2019 (COVID-19) pandemic noted an increase in SCA incidence

and decline in survival from SCA.[3] However, as COVID-19 variants and infection/vaccination rates evolved, a longer study spanning at least 2 years of the pandemic could provide current and useful information. The U.S. Hispanic population has experienced a higher incidence of COVID-19 than the non-Hispanic White population,[4,5] with disproportionate

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increases in overall cardiovascular mortality during the pandemic.[6] In an earlier study conducted prepandemic, we reported that Hispanic and non-Hispanic White residents of Ventura County, California, had similar age-standardized incidences of SCA.[7] In the present analysis, we tested whether the incidence of SCA increased and survival from SCA decreased among all residents of Ventura County, California, during 2 years of the COVID-19 pandemic and evaluated whether potential changes differed by ethnicity.

Methods
Setting
Individuals with out-of-hospital SCA from March 1, 2016, through February 28, 2022, were identified from the ongoing population-based PRESTO (PREdiction of Sudden Death in MulTi-Ethnic COmmunities) study in Ventura County, California.[7] In this study, all incident cases of presumed SCA requiring cardiopulmonary resuscitation and/or defibrillation by the county's 2-tiered Emergency Medical Services (EMS) system were prospectively identified and adjudicated by study physicians based on detailed review of the EMS prehospital care report, prearrest and at-arrest medical records, death certificates, and autopsies when available. Adjudicated SCA was defined as a sudden, unexpected pulseless collapse of likely cardiac origin.[8] All cases with an identifiable noncardiac etiology, such as trauma, drug overdose, and chronic terminal illness (eg, malignancy not in remission), were excluded. The PRESTO study was approved by the Institutional Review Boards of the Ventura County Medical Center, Cedars-Sinai Medical Center, and all participating health systems. All survivors of SCA provided informed consent; for nonsurvivors, this requirement was waived. This report follows the STROBE guidelines for reporting results of observational studies.[9] (Deidentified participant data will be made available after publication upon reasonable request to the corresponding author, following approval of a proposal and a signed data use agreement.)

Outcomes
The primary outcome was incidence of SCA. A secondary outcome was survival to hospital discharge (STHD) following SCA.

Definition of ethnicity
Race and ethnicity were obtained from death certificates for the majority of cases (87%), and also from medical records or interviews with survivors. Death certificates for defining Hispanic ethnicity have a positive predictive value of 91.3% compared to self-report.[10] Missing ethnicity (4%) was imputed by surname based on U.S. Census data.[11] Individuals of Hispanic ethnicity were compared to all other cases.

Variable definitions
Response time was defined as the time between 911 call and EMS personnel arrival at the patient's side. Bystander cardio-

pulmonary resuscitation (CPR) and bystander automated external defibrillator (AED) use were defined as provided by individuals not part of the organized EMS response. Shockable rhythm was defined as ventricular fibrillation/ventricular tachycardia measured by EMS responders (vs other nonshockable rhythms such as pulseless electrical activity or asystole). Survival from SCA was defined as STHD. Socioeconomic status for each case was estimated based on the person's residential address using the Powell-Wiley neighborhood deprivation index (NDI) variable.[12–14]

COVID-19 data sources
Counts of new COVID-19 cases per month for Ventura County were obtained from the California Department of Public Health.[15]

Evaluation of COVID-19 positivity or COVID-related illness in SCA cases
To evaluate whether COVID-19 illness was associated with each SCA case during the pandemic period, we reviewed medical records including a visit to a medical provider within 1 month before SCA, in addition to death certificates, medical examiner notes, and EMS records. We also reviewed cause of death on autopsy if available.

Statistical analysis
To test whether SCA incidence increased overall and to evaluate potential differences by ethnicity (Hispanic vs non-Hispanic), we compared age-standardized incidence per 100,000 during the 2-year COVID-19 pandemic period (March 1, 2020, to February 28, 2022) vs the 4-year prepandemic period (March 1, 2016, to February 29, 2020) in Ventura County, California (2020 population 843,843). To test whether potential pandemic effects on SCA incidence were limited to periods of peak COVID-19 incidence, we compared SCA incidence during pandemic peak and nonpeak periods to incidence in corresponding months in the 4 years prepandemic. Peak periods were defined as months with ≥3000 new reported COVID-19 cases. Nonpeak periods were defined as months with <3000 new COVID-19 cases reported. We also conducted a sensitivity analysis limited to the 2 pandemic years.

We calculated annualized age-standardized incidence of SCA per 100,000 using the overall and ethnicity-specific population of Ventura County, California, in 2020, with the total U.S. population as the standard (U.S. Census Bureau ACS 2020 Tables B01001 and S0101).

To test whether there were differences in arrest circumstances and outcomes due to the pandemic, we compared univariate demographic and arrest circumstances and outcomes in the pandemic vs prepandemic periods with t tests and χ^2 tests, overall and by ethnicity. To test the hypothesis that the pandemic time period had an independent effect on survival from SCA, we estimated adjusted odds ratios for STHD in the pandemic vs prepandemic period in multivariable logistic regression models adjusted for age, sex,

witnessed status (yes/no), response time, bystander CPR, bystander AED, shockable rhythm, NDI, and ethnicity. An interaction term (ethnicity by pandemic period [vs pre]) was used to test for an ethnicity-specific change in STHD during the pandemic. The research reported in this paper adhered to the Helsinki Declaration guidelines. Analysis followed STROBE guidelines[9] using SAS Version 9.4 (SAS Institute, Cary, NC) and a 2-sided significance level of .05.

Results
Overall pandemic vs prepandemic periods

SCA case counts and demographics
The 2-year pandemic period included 907 SCA cases (average 453 per year). The 4-year prepandemic period included 1315 SCA cases (average 329 per year). During the pandemic period, monthly SCA case counts showed a marked increase as monthly COVID counts increased in the second COVID wave (November 2020 to February 2021) (Figure 1). During the pandemic, mean age of SCA cases decreased, a larger proportion of SCA occurred in neighborhoods with lower socioeconomic status as measured by increased neighborhood deprivation index (*P* <.001), and Hispanic individuals accounted for a larger proportion of SCA cases, increasing from 24.3% prepandemic to 31.6% (*P* <.001) (Table 1).

Incidence
Overall age-standardized annual incidence of SCA increased by 38%, from 39 (95% confidence interval [CI] 37–41) per 100,000 before the pandemic to 54 (95% CI 50–57) per 100,000 during the pandemic (Table 2). Among Hispanics,

age-standardized incidence per 100,000 increased by 77%, from 38 (95% CI 34–43) to 68 (95% CI 60–76; *P* <.001) (Table 2). Among non-Hispanics, age-standardized incidence per 100,000 increased by 26%, from 39 (95% CI 37–42) to 50 (95% CI 46–54; *P* <.001) (Table 2). Prepandemic, SCA incidence did not differ by ethnicity (*P* = .62); but during the pandemic, SCA incidence was significantly higher among Hispanics than among non-Hispanics (*P* <.001).

COVID peak and nonpeak months

Incidence compared to corresponding prepandemic periods
During the pandemic, Ventura County had 4 "peaks" of ≥3000 new COVID-19 cases per month, lasting 1 month (first wave, July 2020); 4 months (second wave, November 2020 to February 2021); 3 months (delta wave, July to September 2021); and 3 months (initial omicron wave, December 2021 to February 2022) (Figure 1, gray areas). During combined COVID peak months (11 months total with ≥3000 new COVID cases), the incidence of SCA increased by 18 per 100,000 (*P* <.001) compared to the same months in the prepandemic period (Table 2). During nonpeak periods, the incidence of SCA also increased by 13 per 100,000 (*P* <.001) (Table 2). Among Hispanic individuals, the SCA increase during COVID peak times (32/100,000) was larger than among non-Hispanic individuals (13/100,000). Hispanic individuals also had a larger increase in SCA incidence during nonpeak times (Hispanic 28/100,000 vs non-Hispanic 8/100,000) (Table 2).

When calculated for each peak and nonpeak period separately, SCA incidence increased markedly during the second
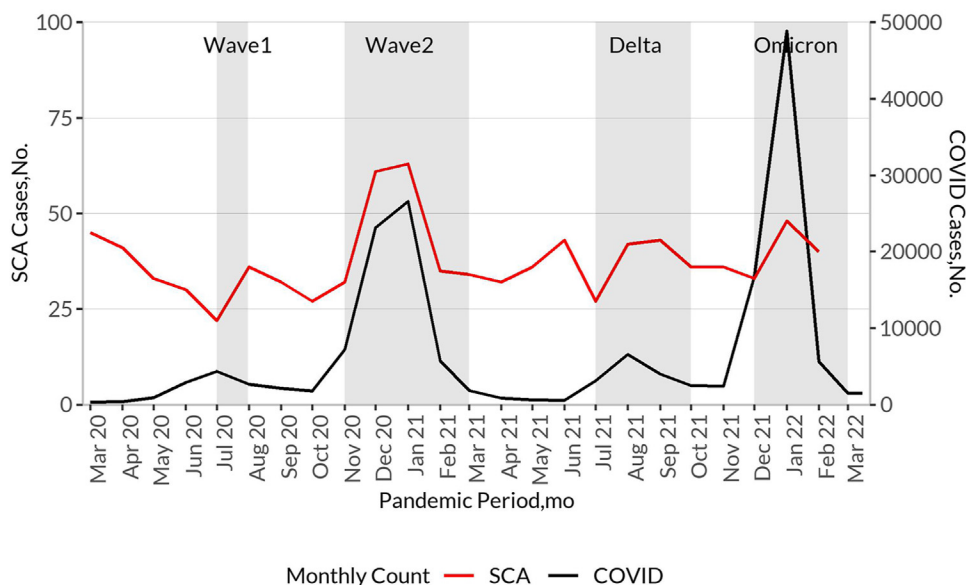
Figure 1 Monthly counts of coronavirus disease 2019 (COVID-19) cases and out-of-hospital sudden cardiac arrest (SCA), Ventura County, California, pandemic period (March 2020 to February 2022). *Black line* indicates new monthly COVID-19 cases. *Red line* indicates new monthly SCA cases. *Gray areas* indicate peaks during the pandemic with ≥3000 monthly COVID-19 cases. Four COVID peak periods were observed: 1 month (wave 1, July 2020); 4 months (wave 2, November 2020 to February 2021); 3 months (delta wave, July to September 2021); and 3 months (initial omicron wave, December 2021 to February 2022). Nonpeak periods were defined as months with <3000 new COVID-19 cases reported (*nonshaded areas*).

Table 1 Characteristics of individuals with out-of-hospital SCA in Ventura County, California, during the 4-year prepandemic period (March 2016 to February 2020) and the 2-year COVID-19 pandemic period (March 2020 to February 2022)

	SCA cases		
	Four-year prepandemic period (n = 1315)	Two-year pandemic period (n = 907)	P value
Race/ethnicity			<.001
White	851 (64.7)	483 (53.3)	
Black	25 (1.9)	22 (2.4)	
Asian	71 (5.4)	60 (6.6)	
Hispanic	320 (24.3)	287 (31.6)	
Other	15 (1.1)	13 (1.4)	
Missing	33 (2.5)	42 (4.6)	
Age (y)	71.3 ± 15.8	69.5 ± 17.0	.01
Male	857 (65.2)	586 (64.6)	.78
Neighborhood deprivation index*			<.001
Least deprivation	225 (17.2)	138 (15.3)	
Below average deprivation	302 (23.1)	144 (16.0)	
Average deprivation	267 (20.4)	211 (23.4)	
Above average deprivation	279 (21.4)	218 (24.2)	
Most deprivation	234 (17.9)	190 (21.1)	
Arrest circumstances			
Witnessed arrest	637 (48.4)	418 (46.3)	.33
Response time (min)	5.0 ± 2.8	6.3 ± 4.1	<.001
Response time >6 min	403 (30.7)	464 (51.4)	<.001
Bystander CPR	742 (56.4)	467 (51.5)	.02
Bystander AED	52 (4.0)	20 (2.2)	.02
Shockable rhythm	335 (25.5)	193 (21.3)	.02
Initial rhythm			<.001
VF/VT	335 (25.5)	193 (21.3)	
PEA	386 (29.4)	214 (23.6)	
Asystole	591 (44.9)	493 (54.4)	
Other	3 (0.2)	6 (0.7)	
Survival to hospital discharge	201 (15.3)	90 (10.0)	<.001

Values are given as n (%) or (mean ± SD) unless otherwise indicated.

Data on witnessed arrest missing for 5 cases during the pandemic period; data on survival to hospital discharge missing for 6 cases during the pandemic period.

AED = automated external defibrillator; COVID-19 = coronavirus disease 2019; CPR = cardiopulmonary resuscitation; PEA = pulseless electrical activity; SCA = sudden cardiac arrest; VF = ventricular fibrillation; VT = ventricular tachycardia.

*Powell-Wiley neighborhood deprivation index, as defined in text, based on U.S. Census block groups.

COVID wave among Hispanic residents (Figure 2A) and remained higher than prepandemic levels throughout the 2-year period, in both COVID peak and COVID nonpeak periods. Among non-Hispanic residents, a smaller increase in SCA incidence was apparent during the second COVID wave, with smaller differences from prepandemic levels throughout the remaining pandemic period (Figure 2B).

Incidence within the pandemic period
Within the 2-year pandemic period, combined peak periods (11 months) had a higher age-standardized annualized SCA incidence at 58 per 100,000 (95% CI 52–63) than combined nonpeak periods (13 months) at 50 per 100,000 (95% CI 46–55) (P = .04). Among Hispanics, SCA incidence increased from 60 (49–70) to 77 (64–90) (P = .04) during nonpeak vs peak periods. Among non-Hispanics, SCA incidence did not change significantly from 48 (43–53) to 52 (46–58) (P = .30). The peaks in SCA incidence in the later COVID surges were less evident (Figures 1 and 2).

Resuscitation circumstances and survival from SCA
Compared to the prepandemic period, EMS response times were prolonged (from 5.0 ± 2.8 minutes to 6.3 ± 4.1 minutes; P <.001), bystander CPR decreased (from 56.4% to 51.5%; P = .02), bystander AED use decreased (from 4.0% to 2.2%; P = .02), and shockable rhythm (ventricular fibrillation/ventricular tachycardia) declined (from 25.5% to 21.3%; P = .02) (Table 1). STHD declined significantly during the pandemic, from 15.3% to 10.0% (P <.001) (Table 1 and Figure 3).

During the prepandemic period, the only ethnicity-specific differences in arrest circumstances were a smaller proportion of Hispanic individuals with an EMS response time >6 minutes and a smaller percentage treated with bystander AED (Figure 4A). Within the pandemic period, Hispanic cases remained less likely to have a delayed response time (>6 minutes) but were also less likely than non-Hispanic cases to have bystander CPR (44.6% vs 54.7%; P = .005) and shockable rhythm (15.3% vs 24.1%; P = .003) (Figure 4B). These differences were not observed

Table 2   Out-of-hospital cardiac arrest incidence in Ventura County, California, during the COVID-19 pandemic (March 2020 to February 2022), overall and during COVID-19 peak and nonpeak periods compared to the corresponding prepandemic periods (March 2016 to February 2020)

	Age-standardized incidence per 100,000 (95% CI)		Age-standardized mean increase in incidence (95% CI)	P value
	Prepandemic period	Pandemic period		
Entire period	n = 1315	n = 907		
All individuals	39 (37–41)	54 (50–57)	15 (11–19)	<.001
Hispanic	38 (34–43)	68 (60–76)	30 (20–39)	<.001
Non-Hispanic	39 (37–42)	50 (46–54)	10 (6–15)	<.001
Peak periods*	n = 625	n = 446		
All individuals	40 (37–43)	58 (52–63)	18 (11–24)	<.001
Hispanic	45 (38–52)	77 (64–90)	32 (17–47)	<.001
Non-Hispanic	39 (35–43)	52 (46–58)	13 (6–20)	<.001
Nonpeak periods*	n = 690	n = 461		
All individuals	38 (35–41)	50 (46–55)	13 (7–18)	<.001
Hispanic	32 (27–37)	60 (49–70)	28 (16–39)	<.001
Non-Hispanic	40 (36–43)	48 (43–53)	8 (2–14)	.01

CI = confidence interval; COVID-19 = coronavirus disease 2019.
*Peak periods were defined as months with ≥3000 new reported COVID-19 cases (Figure 1A). Four peaks were observed: 1 month (first wave, July 2020); 4 months (second wave, November 2020 to February 2021); 3 months (delta wave, July to September 2021); and 3 months (initial omicron wave, December 2021 to February 2022). Nonpeak periods were defined as months with <3000 new COVID-19 cases reported. For prepandemic comparisons, incidence during the combined months of the 4 peak periods was compared to the same months in the prepandemic period. For comparisons of nonpeak periods, all other months during the pandemic were compared to those same months prepandemic.

in the prepandemic period. During the pandemic, the proportion treated with bystander AED was low and was not significantly different by ethnicity.

In univariate comparisons, STHD did not differ significantly by ethnicity in either the prepandemic or pandemic period (Figures 4A and 4B, respectively), despite a somewhat less favorable resuscitation profile among Hispanics (lower bystander CPR and less shockable rhythm) during the pandemic period. The proportion of witnessed arrests, also an important driver of survival, did not decline during the pandemic (Table 1) and was similar by ethnicity within prepandemic and pandemic periods (Figure 4A and Figure 4B, respectively). In bystander-witnessed SCA, bystander CPR declined overall and among both Hispanics and non-Hispanics during the pandemic (P <.03, data not shown).

In a multivariable model adjusted for age, sex, witnessed status (yes/no), response time, bystander CPR, bystander AED, shockable rhythm, NDI, and ethnicity, the pandemic period was associated with significantly lower STHD (adjusted odds ratio 0.68; 95% CI 0.50–0.93; P = .02), with no significant interaction by ethnicity (P = .36). Among survivors, cerebral performance scores were similar during the 2 periods (P = .48).

Potential role of acute COVID-19 illness as a factor in SCA

Sixty-two of the 907 SCA cases (6.8%) during the pandemic period had tested positive for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or had COVID-19 illness at the time of SCA. Of the 62 COVID-associated cases, 52 had COVID-19 mentioned on their death certificates (available for 785 of 811 deceased cases [97%]); an additional 3 were noted at autopsy (available for 132 of 811 deceased cases [16%]); an additional 5 were noted as having a positive COVID-19 test or COVID illness in the EMS report from the time of arrest (available for all 907); and an additional 2 had COVID-19 illness or test positivity mentioned in their medical workup following SCA (available for 36 of 90 survivors [40%]). Of the 62 SCAs associated with COVID, 39 (63%) were Hispanic; mean (± SD) age was 66.1 ± 17.7 years; and 76% were male. Among these COVID-positive SCA cases, 24 (38.7%) were witnessed, 21 (38.9%) had bystander CPR, 1 (1.9%) had bystander AED applied, 9 (14.5%) had a shockable rhythm, and 4 (6.5%) survived to hospital discharge. These arrest circumstances and outcomes were somewhat less favorable than among overall SCA cases during the pandemic.

We also reviewed medical charts for 168 of the 907 SCA cases with a medical visit in the 31 days before SCA. Of these, 55 were inpatient hospital stays. Of the 55, 7 individuals (2 Hispanic) had COVID-related acute illness (pneumonia 5; pneumonia with elevated troponin, ischemia, and sepsis 1; hypoxic respiratory failure 1); and 1 inpatient had an acute myocardial infarction 10 days before SCA and tested positive for SARS-CoV-2 with no acute COVID-19 illness. One additional individual tested positive for SARS-CoV-2 but did not have an inpatient visit or COVID-related illness documented, bringing the total to 9 individuals with evidence of COVID-19 infection in the month before SCA. Of these 9 individuals, 5 were also identified as COVID-associated in the other records noted earlier; and 4 had not been identified through our search of death certificates, autopsies, EMS records, and at-arrest medical records, indicating that they were no longer positive or were not evaluated for COVID-19 positivity at the time of their SCA. Of note, all individuals
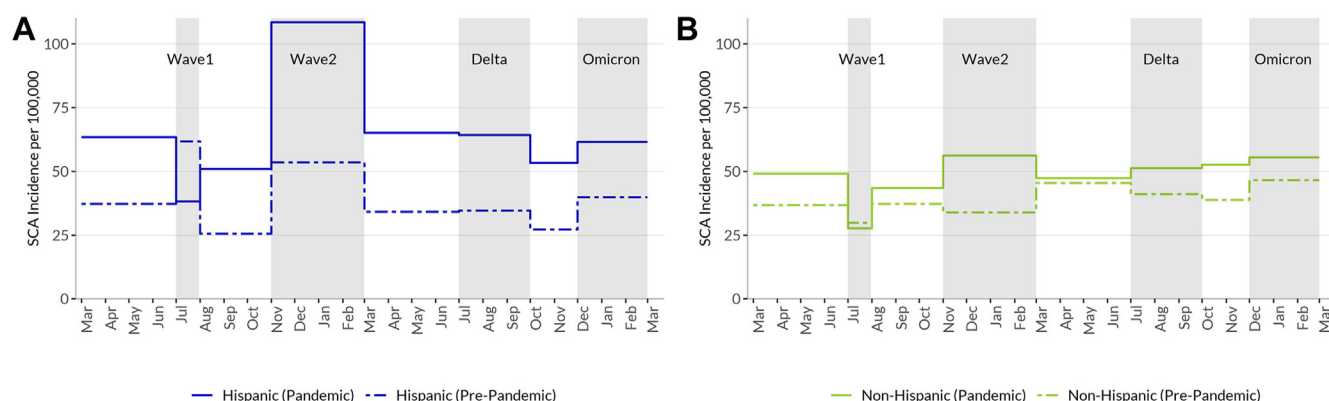
Figure 2   Age-standardized annualized sudden cardiac arrest (SCA) incidence in Ventura County, California, among Hispanics and non-Hispanics during coronavirus disease 19 (COVID-19) pandemic peak and nonpeak periods (March 2020 to February 2022) compared to the same months in the 4-year prepandemic period (March 2016 to February 2020). **A:** SCA incidence among Hispanics during each peak and nonpeak period. Incidence during pandemic periods indicated by *solid blue lines*. Prepandemic periods indicated by *dashed blue lines*. A pronounced increase in SCA incidence was observed in the second COVID wave (November 2020 to February 2021), and incidence remained higher than prepandemic levels in subsequent peak and nonpeak periods. **B:** SCA incidence among non-Hispanics. Incidence during pandemic periods indicated by *solid green lines*. Prepandemic periods indicated by *dashed green lines*. A smaller increase in SCA incidence was observed and incidence remained higher, with less apparent pandemic differences than among Hispanics.

with a hospitalization in the 31 days before SCA had to have been discharged from the hospital before their SCA to be included in our out-of-hospital SCA case group.

Cause of death by autopsy, prepandemic vs pandemic

We compared cause of death in the subset of SCA cases with autopsy in the prepandemic period (available for n = 150/1114 [13.5%]) and the pandemic period (available for n = 133/811 [16.4%]). We limited analysis in the pandemic period to n = 110, excluding 17 individuals whose SCA was attributed to COVID as a main or contributing cause and 6 with pending cause. During the pandemic period, coronary

artery disease accounted for 54.5% of total SCAs, as opposed to 64.7% during the prepandemic period. In the pandemic period, there were increases in the proportion of SCAs attributed to cardiomyopathy (8.2% vs 4.0%), other causes (7.3% vs 2.7%), and SCA/sudden death not attributed to coronary artery disease (5.5% vs 2.7%), whereas congestive heart failure, congenital heart disease, epilepsy, and other causes did not change appreciably.

Discussion

During the first 2 years of the COVID-19 pandemic in Ventura County, California, out-of-hospital SCA incidence increased significantly during the pandemic period, with a
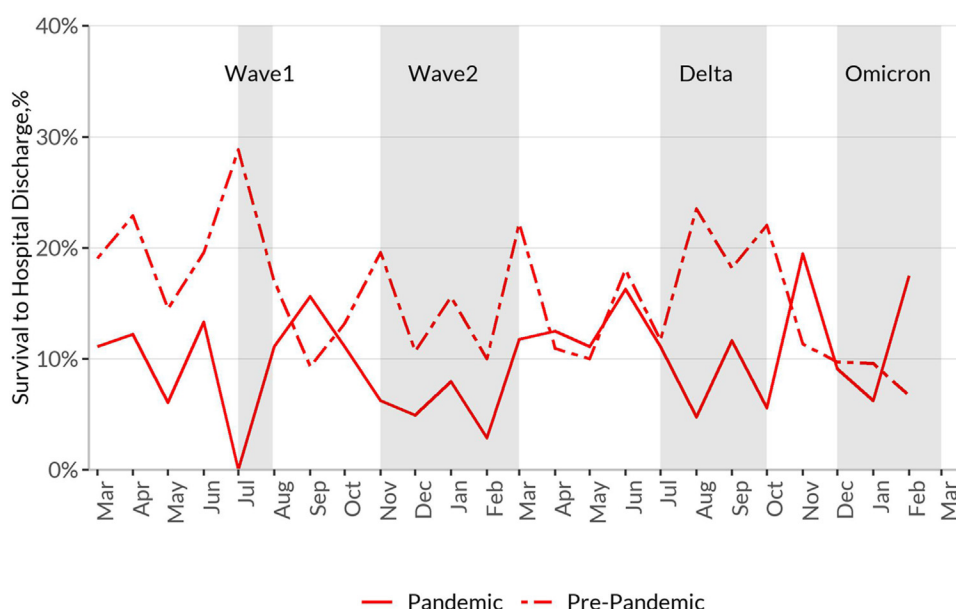

Figure 3   Survival to hospital discharge (STHD) by month, pandemic vs prepandemic. Pandemic indicated by *solid red line*. Prepandemic indicated by *dashed red line*. Monthly percent STHD compared to average monthly percent STHD during the 4-year prepandemic period. STHD was below prepandemic levels during most months of the pandemic, particularly in waves 1 and 2, and the delta wave.
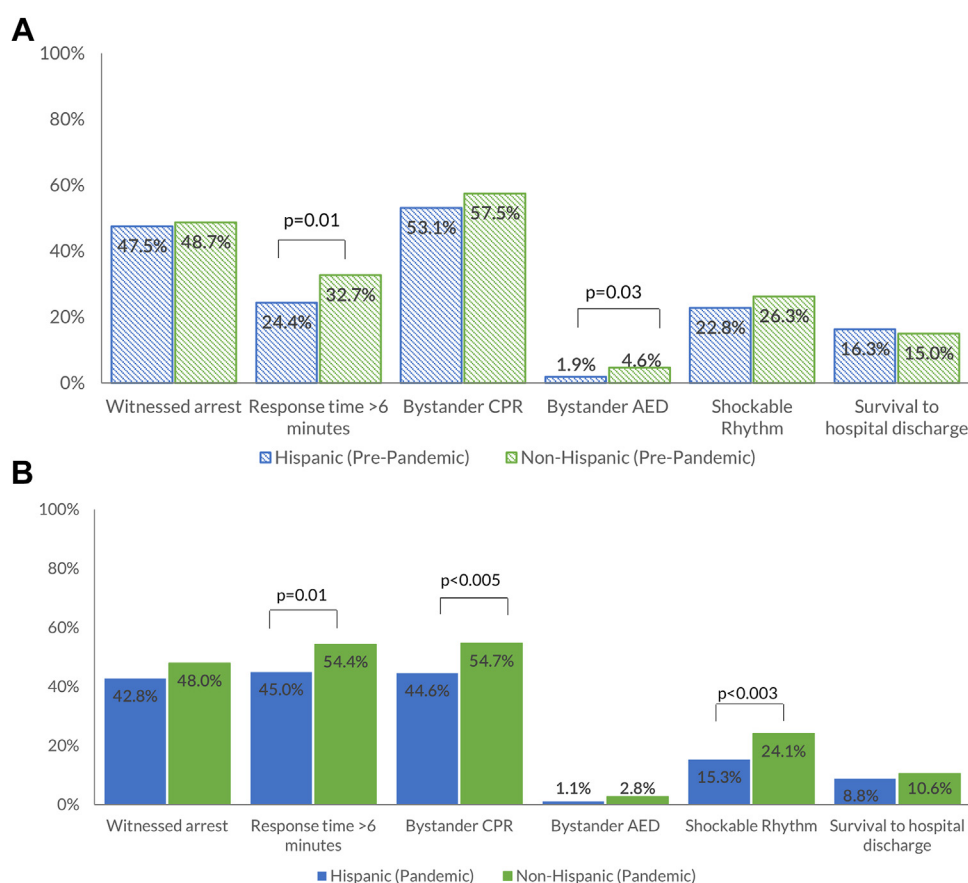
Figure 4 Resuscitation circumstances during pandemic period (March 2020 to February 2022) and prepandemic period (March 2016 to February 2020), Hispanics compared to non-Hispanics. **A:** Ethnicity-specific resuscitation circumstances during prepandemic period (March 2016 to February 2020). Hispanics shown as *blue hashed bars*. Non-Hispanics shown as *green hashed bars*. A smaller proportion of Hispanics compared to non-Hispanics had an Emergency Medical Services (EMS) response time >6 minutes. **B:** Ethnicity-specific resuscitation circumstances during pandemic period (March 2020 to February 2022). Hispanics shown as *blue solid bars*. Non-Hispanics shown as *green solid bars*. Hispanics were less likely than non-Hispanics to have bystander cardiopulmonary resuscitation (CPR) and shockable rhythm. AED = automated external defibrillator.

larger increase among Hispanic individuals (77% higher incidence than prepandemic levels) compared to non-Hispanic individuals (26% higher incidence than prepandemic levels). Coinciding COVID-19 and SCA peaks were observed within the pandemic period, particularly during the second COVID wave (winter 2020–2021). A significant decline in STHD was observed during the pandemic, from 15.3% prepandemic to 10.0%, with no difference by ethnicity. However, reductions in bystander CPR and shockable rhythm were only observed among Hispanics during the pandemic.

Our results are consistent with evidence of increased overall SCA incidence during the COVID pandemic, although most data have been limited to the first 9 months of the pandemic. Evidence from individual cities (eg, Lombardy region in Italy,[16] Los Angeles, California,[17] and Paris, France[18]) suggested that increases in out-of-hospital cardiac arrest (OHCA) occurred during early COVID-19 surges, although data from Western Australia[19] showed no increase in the incidence of OHCA, possibly due to low COVID-19 infection rates. EMS systems from 50 large U.S. cities reported an increase in OHCA of >20% (a few as high as 200%) during early COVID surges, with the timing of

increases in OHCA paralleling COVID-19 surges in those cities.[20] Our finding of peaks in SCA incidence during COVID case surges is consistent with the EMS 50-cities data,[20] but our data show that overall increases in SCA incidence persisted at least through the first 2 years of the COVID-19 pandemic. Multiple factors may contribute to the association of SCA and COVID-19 peaks, including delays in seeking care among individuals with cardiac symptoms[21] and delayed EMS activation/response during COVID-19 waves.[22] Explanations for persistently increased SCA incidence should be explored. Our data showed a marked peak of SCA with the wave 2 peak of COVID-19, but less obvious corresponding peaks of SCA during the delta and omicron waves. These observations may be hypothesis-generating regarding potential associations between community-wide vaccination levels, a reduction in COVID-19 illness severity, and a decoupling of SCA incidence from COVID-19. During wave 2, <15% of the Ventura County population had received at least one 1 dose of vaccine; this percentage had risen to 70% during the delta wave and 78% during the omicron wave. However, it is possible that other community-wide changes in behavior

later in the pandemic (eg, adaptations in the EMS system, or a return to individuals' prepandemic patterns of engagement with the medical system) may also help to explain the decoupling of SCA with peaks in COVID-19 incidence.

Few studies of OHCA/SCA during the pandemic have included data on COVID-19 test positivity or acute illness. One such study reported that of 537 OHCAs from February 26 through April 15, 2020, in King County, Washington (Seattle area), 6.5% of EMS-treated OHCA had a positive polymerase chain reaction test for SARS-CoV-2 or a COVID-like illness (febrile or respiratory illness) based on review of medical records and death certificates.[23] Testing for COVID-19 was likely not systematically performed for SCA victims at any time during the pandemic in Ventura County. Therefore, our finding of 6.8% COVID positivity likely is an underestimate of those who were COVID-positive.

Regarding the burden of COVID among Hispanics, a number of studies have reported higher COVID-19 test positive rates, hospitalizations, and deaths due to COVID-19 among Hispanic individuals,[5,24,25] likely due to a variety of factors including systemic issues that disproportionally increase risk or severity of COVID-19 infection among Hispanics, such as working in an essential industry, being more likely to have close contact with COVID-19 affected individuals,[26] and having differential health care access.[27] Because COVID-19 infection increases risk for thrombosis, a higher infection rate among Hispanic individuals could translate to a higher event rate for conditions due to thrombosis. Evidence from England and Wales showed an adjusted hazard ratio of 22.1 for myocardial infarction in the first week after COVID-19 diagnosis vs no COVID-19 diagnosis.[28] Whereas Hispanic individuals accounted for 31.6% of SCA cases during the pandemic, among the 6.8% SCA cases with positive SARS-CoV-2 test or COVID-19 illness at the time of SCA, 63% were Hispanic.

Poorer survival from SCA during the pandemic has been fairly well established. A meta-analysis of 20 studies from 10 countries reported a lower STHD (pooled odds ratio 0.52; 95% CI 0.40–0.69) during the pandemic.[29] Few previous studies have provided direct evidence of a differential impact of the pandemic on SCA by race or ethnicity, and these were conducted early in the pandemic. In New York City from March 1 to April 25, 2020, SCA cases attended by EMS were twice as likely to be Hispanic compared to the year before.[30]

Our findings of less favorable resuscitation characteristics during the pandemic among Hispanics in Ventura County are a cause for concern. In a pandemic setting, community participation in bystander CPR likely drops due to fear of contracting infection, and reductions have been reported previously.[22] Bystander CPR is an established predictor of successful resuscitation leading to a doubling of survival from SCA,[31] and studies in some communities have reported lower bystander CPR rates in neighborhoods with a higher proportion of Hispanic residents.[32,33] In our study population, prepandemic differences in bystander CPR were not evident, suggesting the pandemic may have introduced

disparities. Presentation with a shockable rhythm is a critical determinant of survival following resuscitation.[31] Lower rates of shockable rhythms among Hispanics are likely to have more complex explanations. Hispanics may be more likely to delay contact with the health care system[34] for COVID as well as non-COVID illnesses, such as acute coronary syndromes, potentially leading to presentation to EMS providers with more critical illness. Ethnicity-specific differences in baseline clinical profile, such as obesity, diabetes, and renal disease, may also contribute.[7] Our findings should be evaluated in the context of the consistently high bystander CPR rates (56% prepandemic) in Ventura County compared to those in all of California (40.5%)[35] and the overall bystander CPR rate (39.2%) reported across 764 EMS agencies in the United States.[36] Ventura County has conducted hands-only CPR training free of charge throughout the community for many years, with fire departments, ambulance companies, hospitals, and other community organizations participating. Dispatcher-assisted CPR is available to all callers in the community through a single center, with comprehensive language translation. These community-wide efforts could explain the lack of ethnicity-specific differences in bystander CPR we observed in the prepandemic era. Decreases in bystander CPR rates could be due to myriad disruptions caused by the pandemic but may have been smaller than those experienced in other communities that have not made equitable investments in CPR education campaigns. Our data suggest there could be opportunities to improve resuscitation characteristics among Hispanics by targeted awareness and education approaches at the community level.

Study limitations
Due to the lethality of SCA, most ethnicity data were obtained from death certificates rather than self-report. However, this method has been shown to have a positive predictive value >90% for identifying Hispanic individuals relative to self-report,[10] and errors in death certificate–determined ethnicity tend to under-ascertain Hispanic individuals.[37] Therefore, our results regarding the impact of the pandemic on SCA among Hispanics are likely an underestimation. Autopsies were available for <16% of SCA cases and indicated that causes other than typical coronary artery disease may have played a larger role during the pandemic. However, these proportions were based on small numbers, so these results must be viewed cautiously.

Conclusion
The first 2 years of the COVID-19 pandemic have led to persistently higher SCA incidence, with disproportionately higher increases among Hispanics in this population. Survival from SCA has also decreased, with less favorable resuscitation profiles in Hispanics. These findings implicate potential ethnicity-specific barriers to access to acute care during the pandemic and represent an urgent call to action at the community as well as health system levels.

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